#5 N.E.

~~NUMERICALLY CONTROLLED METHOD~~

NUMERICAL CONTROL METHOD INCLUDING INSERTING TIME VARIABLE INTO SPATIAL POLYNOMIAL FOR CONTROLLING OBJECT MOTION

BACKGROUND OF THE INVENTION

[0001] This invention relates to a numerically controlled method capable of machining ~~on~~**along a** curved face ~~and~~**or** the like**,** at high accuracy.

[0002] FIG. 7 is a typical view ~~for~~ showing a conventional servo control. ~~When~~**In this example,** servo control ~~of each axis~~ is performed **on each axis** using three dimensional spatial position ~~command,~~**commands. Such** a conventional servo control 60 ~~to~~**can** be used**, e.g.,** for a laser beam machine ~~and a~~**apparatus. A** machining ~~center~~**central control** makes ~~an~~ axis ~~command producing~~**commands, causing** portion 50 to produce ~~the~~ moving ~~command concerning each control axis~~**commands as** necessary for ~~realizing~~**each control axis. The commands move the controlled apparatus so as to comply with** spatial position ~~command~~ and velocity ~~command instructed by~~**commands according to** a machining program ~~on the basis of the spatial position command and the velocity command~~.

[0003] The moving command concerning each axis**,** produced in this way**,** is output to **a** corresponding axis control portion~~, and the~~**. The** axis control portion drives a motor on the basis of the moving command. At ~~this~~**the same** time, feedback **control** is executed ~~on a~~**, using** position, velocity and acceleration of the motor ~~every sampling time so~~ as **inputs** to compute proper velocity and proper acceleration of the motor **for each successive sampling time**.

[0004] In such a method ~~of determining~~**wherein a** control parameter, such as velocity~~,~~ ~~and~~ **or** acceleration, ~~by~~**is determined based on** feedback,~~but~~ the control parameter is computed on the basis of ~~such a state that an axis is already out of~~**the sampled difference from** a target ~~in~~**value during** a sampling time. Therefore, the control axis to

be controlled by the control parameter is not controlled on the basis of the **instantaneous** state of the control axis ~~in a present time~~, but on the basis of the state of the control axis ~~before~~**as of** a predetermined **earlier** sampling time~~, then,~~**. There is a** delay ~~generates concerning~~**in** the control. When machining is executed at high feeding speed ~~or~~**, or when programming requires the** tool locus ~~suddenly curved is programmed~~**to execute a sharp curve**, errors ~~accumulates~~**accumulate** owing to control delay. ~~Then, it is~~ **It can become** difficult to **control the tool** properly ~~control~~. In the servo control 60 as shown in FIG. 7, for instance, ~~the~~ spatial position ~~command~~**commands** PC ~~which is~~**that define** a track in a working space ~~wherein~~**along which** a tool moves (**a** three dimensional space), and ~~the~~ velocity ~~command~~**commands VC,** are given to ~~the~~**an** individual axis command producing portion 50 (in ~~this case,~~**the example, a** velocity override command OC **also** may be given to the individual axis command producing portion 50). Receiving these commands PC, VC, the individual axis command producing portion 50 produces ~~the~~**a** position command Dn **for** every sampling time s ~~determined~~**, which determine values** including acceleration and deceleration ~~concerning~~**for adjusting** each **controlled** axis Sn (n=1, 2, . . . , 5) ~~to be controlled~~.

[0005] An axis control portion 51 of each axis Sn produces the velocity command and the acceleration command (or power command) necessary for servo control from the position command Dn of the axis Sn, and executes axis servo control through a power control portion 56 for controlling electric power ~~of~~**applied to** a motor M ~~concerning~~**associated with** the axis Sn ~~in such a manner that position~~**. Position** control **is performed** on the basis of ~~the~~**a** position command Dn ~~is performed by~~**applied to** a position **control** loop ~~52,~~**52;** velocity control on the basis of ~~the velocity~~ **a velocity** command is performed by ~~a velocity~~ **a velocity** loop ~~53,~~**53;** acceleration control on the basis of ~~the~~**an** acceleration command is performed by an acceleration loop ~~55.~~ **55, etc. These elements are parts of the control portion 51, and have control loop and feedback relationships as shown in FIG. 7.**

[0006] ~~But, the control~~**The controls** of velocity and acceleration ~~has~~**have** delay ~~element~~**elements** in this conventional servo control ~~60 since~~**60. For each axis SN,** the **present** velocity command and ~~the~~ acceleration command **in axis control portion 51** are ~~produced~~**based** on ~~the basis of~~ the state of the control axis at ~~this time in axis control portion 51 of each axis Sn~~**predetermined earlier time**. In particular, ~~an~~ influence of **the** delay element ~~is bigger~~**can be large** in **executing** spline interpolation ~~to be executed as micro division~~**and the like, as compared to time subdivisions** for straight line interpolation (or circular arc interpolation). ~~Therefore, the~~**In that case,** movement of the working point, which is ~~the~~**a** composite movement ~~of~~**involving** each axis, is not smooth and includes irregularity. The control ~~becomes to be one including track~~**produces a tracking** error between the commanded track and the **actual** track of the working point.

[0007] ~~Besides, when ideal~~**Furthermore, the object may be to** control ~~object wherein~~**along a** nonlinear ~~element which the machine of control object has is~~**track. If such an aspect has** not **been specially** considered, ~~is controlled in this~~**and the conventional** control system **is used to effect such a control**, it ~~is~~**may be** necessary to ~~control concerning~~**deal with a** sudden change of velocity and acceleration~~, if~~ **when following the** spatial position ~~command is~~**commands** along ~~the~~**a** track having ~~bigger~~**an abrupt** curvature, as already mentioned ~~concerning~~**with respect to** spline interpolation or the like. In a conventional ~~way~~**control**, the velocity command and the acceleration command in ~~this~~**the axis** control **portion 51** are ~~produced~~**determined** from **an error between** the **present** position ~~command of~~**and ideal position during the** present sampling ~~time in the axis control portion 51, then~~**interval. As a result,** sufficient control is impossible. ~~Then, the~~**The** error between the actual position and the command **ideal position** is made bigger. ~~In the result, feeding irregularity which is integration of the acceleration and position shift which is the integration of the feeding irregularity generate~~ **Feeding irregularities are generated and carried forward in the control response to new changes in position, integrated with the results of previous control moves**.

[0008] ~~The~~**An** object of the present invention is to provide a numerically controlled method capable of reducing feeding irregularity or position shift and executing curved face machining at high accuracy, taking the above-mentioned circumstances into consideration.

SUMMARY OF THE INVENTION

[0009] ~~The~~**According to one aspect, the** invention ~~of claim 1 is numerically controlled~~**is a numerical control** method ~~of~~**for** moving an object to be controlled along a predetermined locus, ~~controlling~~**by positioning the object relative to** control axes, ~~said~~**the** method comprising:

[0010] making said locus approximate to a spatial polynomial;

[0011] converting said **spatial** polynomial into a polynomial ~~as~~**having a** time function;

[0012] distributing said polynomial**,** converted ~~as~~**to have the** time function**,** to ~~said~~ each **said** control axis;

[0013] producing **a** control command in said each control axis on the basis of said polynomial**,** distributed to ~~said~~ each **said** axis ~~as~~**and having said** time function; and

[0014] moving said object to be controlled along said locus, controlling each control axis on the basis of said control command.

[0015] ~~According to claim 1,~~**In this way,** the velocity, the acceleration, the jerk of a top end of a torch (or ~~a top end of a~~**of some other object or** tool) can ~~be~~ easily **be** obtained ~~concerning~~**as to** each control axis without **a sampling** time delay**. This result is obtained** by deriving ~~the~~**a** polynomial **for positioning of the locus,** converted into **a** time function. Each control axis is driven and controlled on the basis of the control parameter, such as the velocity and the acceleration obtained in this way. Therefore, ~~the~~ preview control **is made possible** wherein **the** future ~~moving state~~**motion** of ~~an~~**the** object to be controlled ~~is foresaw and control is executed so as to correspond with the foreseeing is possible. By doing so~~**can be foreseen. It is possible to control positioning movements in part based on foreseen future motion parameters. By**

so doing, it is possible to provide a ~~numerically controlled~~**numerical control** method wherein the motion of the object to be controlled is ~~correctly~~**more precisely** controlled ~~along~~**to follow** the locus expressed by the polynomial~~,~~**. Any** feeding irregularity or position shift is reduced~~, and machining~~**. Machining along** on curved face or the like can be executed at high accuracy.

[0016] ~~The invention of claim 2 is the~~**According to another aspect, in a** numerically controlled method~~ wherein said~~**, the** control command is produced on the basis of a position command ~~on the basis of~~**obtained at least partly from** said polynomial converted ~~as~~**to contain a** time function~~, a~~**. A** velocity command **can be** obtained ~~by~~**from the** first ~~deriving said~~**derivative of the** polynomial ~~converted~~ as ~~time~~**a** function~~, and an~~ **of time. An** acceleration command **can be** obtained ~~by~~**from a** second ~~deriving said~~**derivative of the** polynomial ~~converted~~ as ~~time~~**a** function **of time**.

[0017]~~ Furthermore, the control command~~**Control commands** can be obtained by using ~~the~~**a** polynomial having **a** third or higher degree than third**. Furthermore, third or higher derivatives can be employed**, such as ~~the~~**a** jerk command ~~obtained by~~**(from a** third ~~deriving~~**derivative of** the **time-**converted polynomial~~ as the time function~~**)**.

[0018] ~~The invention~~**One aspect** of ~~claim 3 is the numerically controlled~~**the numerical control** method ~~wherein said~~**is to generate** control ~~command is~~**commands to be** executed by computing a position and **a** velocity ~~at the~~**for a** time in **the** future**, providing a control input** when said object to be controlled has not yet moved**. This input is determined** on the basis of said polynomial ~~as~~**containing a** time function and ~~commanding~~**affects control commands that are applied at a later time**.

[0019] According to ~~claim 2 or claim 3,~~**the invention,** position ~~command~~**commands**, velocity ~~command and~~**commands,** jerk ~~command~~**commands, etc.** can be produced **based on previewed or predicted positioning error, enabling control** without **a sampling** time delay~~, preview control is possible. Even in~~**. It becomes easy to deal with even a** case where **the** velocity vector or acceleration vector is ~~suddenly changed concerning each control axis as suddenly curved line, it is easy to deal with~~**abruptly**

changed for one or more of the control axes, for example when encountering a sudden sharp curve in a line to be followed by the object.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1 is a block diagram ~~for~~ showing a **control** structure ~~of~~**for positioning** control of a laser beam machine ~~in the present~~**tool, as an exemplary** embodiment;

[0021] FIG. 2 is a ~~typical~~**schematic block diagram** view ~~for~~ showing a ~~serve~~**servo** control;

[0022] ~~FIG. 3 is a view for showing an exterior of the laser beam machine in the present embodiment;~~ **FIGS. 3a and 3b are perspective illustrations of aspects of laser beam machine tools, with different reference axes labeled;**

[0023] FIG. 4 is a flowchart ~~for~~ showing an example of ~~multiaxis~~**multi-axis** control program (algorithm);

[0024] FIG. 5 is a view for showing a process of producing command of each control axis concerning a curved line of two dimensional plane;

[0025] FIG. 6 is a view for showing a process of producing command of each control axis concerning a curved line of two dimensional plane; and

[0026] FIG. 7 is a typical view for showing a conventional servo control.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] Embodiments of the present invention will now be explained ~~hereinafter~~, referring to **the** drawings.

[0028] FIG. 3 is a view ~~for showing an~~**of the** exterior of a laser beam machine in ~~the present~~**an exemplary** embodiment. A laser beam machine 1 in ~~the present~~**this**

embodiment has a base ~~2,~~**2** and a table 3 ~~is provided~~ on the base 2, **the table** being free to move and drive in a horizontal X axis direction, as shown in FIG. 3 (a). On the table 3, a workpiece W to be machined can be ~~located~~**placed**. A column 5 is provided on the base 2, bridging over the table 3, and the column 5 has a saddle ~~6, being~~**6 that is** free to move and drive in a horizontal Y axis direction (~~the~~**a** direction orthogonal to the X axis direction).

[0029] The saddle 6 has a head unit 7, which is free to move and drive in **the** Z axis direction **(orthogonal to X and Y)** which is **the** up and down direction **in the orientation shown in the drawing**. The head unit 7 is comprised of a first portion 7a on the **side of** saddle ~~6 side,~~**6,** a second portion 7b~~, being~~ **that is** free to rotate and drive in **the** A axis direction with respect to the first portion 7a with an axial center CT1 of the first portion 7a parallel to the Z-axis as its center~~, a~~**. A** third portion 7c~~, being~~ **is** free to rotate and drive in B axis direction with respect to the second portion 7b with a horizontal axial center CT2 of the second portion 7b as its center~~, and a~~**. A** torch 7d provided on the top end side of the third portion 7c, as shown in FIG. 3 (b). ~~Besides, a~~**A** laser beam generating means (not shown) is provided ~~being free~~**and is operable** to inject laser beam from the torch 7d.

[0030] As mentioned before, the laser beam machine 1 performs three dimensional machining on the workpiece W**,** in such a manner that **the** relative positional ~~relation~~**relationship** between the workpiece W**,** located on the table ~~3~~**3,** and the ~~top~~**working** end of the torch 7d**,** is three-dimensionally changed~~,~~**. This is accomplished by** driving and positioning the table 3 in the X axis direction, the saddle 6 in the Y axis direction, the head unit 7 in the Z axis direction**,** and **rotationally driving and positioning** the torch 7d in the A axis direction and **in** the B axis direction~~ and~~**, while injecting a** laser beam ~~is injected~~ from the torch 7d **at the required times**.

[0031] FIG. 1 is a block diagram for showing ~~a structure~~**the elements** of **a** control ~~of~~**for positioning** the laser beam machine in the present embodiment. The laser beam machine 1 has a main control portion 20, as shown in FIG. 1. The main control portion

20 has a machining program memory portion 21, a polynomial generation computing portion 23, an individual axis command producing portion 26, an axis control portion 27, a power control portion 35 and the like. A servo control 25 is comprised of the individual axis command producing portion 26 and the axis control portion 27.

[0032] The laser beam machine ~~1 is comprised as~~**1, containing the elements** mentioned~~before. Then~~, **executes** machining **operations** on the workpiece W ~~with the laser beam machine 1 is executed~~ as follows. In advance, a worker composes **a** machining program PR by ~~teaching (in this case, this machining program PR may be composed with a CAD and a CAM). The~~**programming operations, potentially with the assistance of CAD and CAM software, and stores the** machining program PR ~~composed is stored~~ in the machining program memory portion 21 of the laser beam machine 1, as shown in FIG. 1.

[0033] ~~After a command of~~**When a worker initiates** machining **by operating a** start ~~is input by a worker~~**command**, the main control portion 20 ~~reads out~~**accesses** the machining program PR**,** stored in the machining program memory portion ~~21 on~~**21. On** the basis of ~~this~~**the program PR and the start** command,~~and~~ the polynomial generation computing portion 23 produces a time parameter type polynomial P(t) ~~on~~**corresponding to** the ~~basis of a spatial position command PC for commanding moving position of the torch~~**spatial position commands PC that otherwise define the movement and relative positions of the torch over the workpiece. In addition to a spatial path** with respect to the workpiece, ~~and~~**this produces** a velocity command VC which is the ~~moving~~ velocity at ~~this time which are shown~~**which the torch or other object is to progress along the moving locus defined** in the machining program PR~~,~~ ~~that is, on the basis of relative moving locus of a tool.~~**.** Subsequently, the individual axis command producing portion 26 produces commands, such as **a** position command D1, velocity command α_S, acceleration command β_S and jerk command γ_S for relatively moving the torch 7d with respect to the workpiece on the table 3 on the basis of the time parameter type polynomial P(t) so as to **provide a controlling** output to the axis control portion 27 of each **controlled** axis.

[0034] FIG. 2 is a typical view for showing a servo control, and axes S1, S2, S3, S4, S5 respectively correspond to X axis, Y axis, Z axis, A axis and B axis.

[0035] That is, from the spatial position command PC ~~for commanding~~**that determines the** relative~~-moving~~ position of the torch with respect to the workpiece **when moving relative to the workpiece**, and a velocity command VC which is ~~the moving~~**a** velocity ~~at this time~~**during such movement,** which are ~~shown in~~**provided from** the machining program PR, the polynomial generation computing portion 23 **first** produces a spatial polynomial ~~for~~**that** approximately ~~expressing~~**expresses** the tool locus **or path** in~~-a~~ space ~~produced~~**as defined** by these **stored** commands, as shown in step S1 of ~~multiaxis~~**multi-axis** control program MAC of FIG. 4. ~~This~~**Generation of the spatial polynomial** makes use of ~~such a~~**the** known property that an ~~optional~~**arbitrary line (optionally a** curved line ~~(including~~**or** a straight line) in ~~a-~~space can be approximated by a polynomial, such as **a** spline function or **a** NURBS function**,** after dividing **the line** into a plurality of line elements, as shown in FIG. 4. The following vector operation expression is obtained, for instance, as shown in expression (A1) of FIG. 4. That is,

$$P(\gamma)=A\gamma^3+B\gamma^2+C\gamma+D \qquad \text{(A1)}$$

[0036] By this polynomial, a straight line, an arc or the like can be correctly expressed in addition to a spline curved line. If the axes to be controlled ~~is~~**are** three axes, that is, X, Y, and Z, for instance, the expression (A1) can be developed as shown in an expression (A2).

[0037] ~~Then~~**Next**, the ~~mutiaxis~~**multi-axis** control program MAC enters into step S2, **wherein** γ of the spatial polynomial is expressed as function of time t as follows.

$\gamma=\alpha(t)$ (α is a function of t)

t=moving distance/feeding velocity

[0038] The spatial polynomial (A1) is converted into the following expression by substituting $\gamma = \alpha(t)$

$$P(\alpha(t)) = A(\alpha(t))^3+B(\alpha(t))^2+C(\alpha(t))+D \qquad (A3)$$

[0039] ~~Then, this~~**In this way, the spatial polynomial defining the path of the tool** is converted into **a** time parameter type polynomial (A3).

[0040] ~~Then, the~~**The** tool locus ~~instructed~~**or path defined** by the machining program PR is **thereby** expressed ~~by the~~**as a** time function ~~which is~~**, such as** the expression (A3). ~~Thereafter~~**At a given time**, an expression ~~for~~ representing a position **of the tool** can be obtained from the time parameter type polynomial (A3), an expression ~~for showing~~**representing** velocity ~~is~~**can be** obtained by differentiating the polynomial (A3**) (that is, from the first derivative**), an expression for showing acceleration is obtained by differentiating the expression ~~for showing~~**representing** the velocity **(the second derivative of polynomial (A3)**, and furthermore, an expression for showing jerk is obtained by differentiating the expression for showing the acceleration**. Such computations can be provided** in step S3 of the ~~multiaxis~~**multi-axis** control program MAC. These expressions are output to the individual axis command producing portion 26, and the individual axis command producing portion ~~26~~**26, which** can immediately obtain ~~the~~**nominal** position, ~~the~~ velocity, ~~the~~ acceleration and ~~the~~ jerk **values,** in objective sampling time **and** without **a sampling** time delay**,** by substituting a predetermined sampling time ~~in~~**value into** the expression.

[0041] ~~That is, the~~**A feedback control normally responds in a current interval an error in position or the like determined during by sampling during a previous interval. However, the nominal** velocity, ~~the~~ acceleration and ~~the~~ jerk of the top end of the torch**,** at ~~an optional~~**any arbitrary point in** time**,** can be ~~easily~~ obtained **easily according to the present invention** without ~~having~~**such** delay ~~element~~**,** by differentiating the time parameter type polynomial**, or spatial locus** expressed ~~by the~~**as a** time function. ~~After~~**At least in part from the calculated information,** the tool locus, ~~that is, the~~**a** velocity command, ~~the~~**an** acceleration command and ~~the~~**a** jerk command

~~of~~**for** the top end of the torch ~~are~~**can be** obtained in this way~~, the~~**. The** expressions ~~for showing~~**representing** the position, ~~the~~ velocity, ~~the~~ acceleration and ~~the~~ jerk of the top end of the torch are distributed with respect to each control axis ~~comprising~~**defining the** joint space, using inverse kinematics and inverse Jacobian or the like at step S4 of the ~~multiaxis~~**multi-axis** control program MAC ~~so as to obtain the~~**. This produces** expressions ~~showing~~**for** the velocity, the acceleration and the jerk ~~concerning~~**, applied as inputs to** each control axis.

[0042] The individual axis command producing portion 26 obtains the velocity, the acceleration and the jerk of each axis **for a given point** in ~~an optional~~ time from the obtained expressions showing the velocity, the acceleration and the jerk concerning each control axis at step S5 of the ~~multiaxis~~**multi-axis** control program MAC ~~so as to~~**, and uses these values in determining the** output to the axis control portion ~~27 as~~**27, namely** position command Dn, velocity command α_s, acceleration command β_s (or power command) and jerk command γ_s. Since the **nominal** velocity, ~~the~~ acceleration and ~~the~~ jerk at an optional time in future can be obtained in advance **by mathematical computation**, it is sufficient for the axis control portion 27 of each axis to control each axis only ~~so as to make the~~**to correct if necessary to obtain such** velocity, ~~the~~ acceleration and ~~the~~ jerk **values, equal to values that can be** obtained in advance ~~in~~**for** each sampling time ~~in~~**. These values can be predicted for a** future **moment in time** (preview control). ~~Then~~**In this way**, correct control with no time delay is possible. ~~Therefore, its~~**The** transfer function G(S) ~~unlimitedly approximates to 1~~**of the control approaches unity** as shown in step S6 and the expression (A4)~~, and then, correct~~**. Correct** machining **is made possible,** without ~~shape~~**the introduction of shaping** error ~~is possible~~**by the control**. It is also possible **vary from this, however, such as** to give a velocity override command OC to the individual axis command producing portion 26.

[0043] The axis control portion 27 of each axis Sn executes axis servo control through the power control portion 35 for controlling electric power of a motor M concerning the axis Sn, using the received position command Dn, the velocity command α_s, the acceleration command β_s (or power command) and the jerk command γ_s in such a

manner that position control on the basis of the position command Dn is performed by a position loop 30, velocity control on the basis of the velocity command α_s is performed by a velocity loop 31, acceleration control on the basis of the acceleration command β_s is performed by an acceleration loop 32, and jerk control on the basis of the jerk command γ_s is performed by a jerk loop 33.

[0044] As mentioned before, the relative positional relation between the top end of the torch 7d of the laser beam machine 1 and the workpiece W is three-dimensionally changed by performing axis servo control in each axis Sn~~, moving the~~**. The** top end of the torch 7d **may be moved** in~~ a~~ space at a constant velocity, and the workpiece W is three-dimensionally machined ~~as~~**by the laser beam from torch 7d, so as to shape the workpiece according to** the above-mentioned machining program PR~~ by injecting laser beam from the torch 7d~~. The polynomial which **the** moving **tool** locus approximates is expressed by ~~time axis~~**a** function~~,~~ **with space** and ~~the~~**time variables. The** position, the velocity, the acceleration and the jerk at ~~the~~**a given time, including a** time in **the** future ~~in~~**during** the process of moving the torch**,** are computed in advance and ~~are commanded. Then, the~~**incorporated into the control commands. As a result, the control avoids** generation of machining ~~irregularity~~**irregularities** owing to sudden ~~change of moving~~**changes in** velocity and/or ~~moving~~ direction ~~can be saved, and accurate~~**while progressing along a programmed path. Accurate** machining is possible by the torch to be controlled on the basis of the polynomial.

[0045] Since ~~a~~**the** track **according to this embodiment** is approximated by a polynomial on the basis of **a** time ~~axis~~ function~~ in the control system in the present embodiment~~, **no** position shift ~~does not happen owing to the control system, but only position shift in approximation of spatial position command happens. When accuracy is obtained in this control system, it is sufficient to~~**is introduced simply from the operation of the control system. Errors may occur, for example, wherein the actual sampled spatial value or the like differs by an error value from the desired value. However if an error occurs, the control of the invention, which already**

responds to calculated values, needs only **to** take **into account** the error at the command stage into consideration. So, it is easy to control accuracy.

[0046] An example wherein the present invention is applied to the control of tool locus (torch locus) on two dimensional plane is shown in FIGS. 5 and 6. When a curved line LIN of X-Y plane is expressed as **a** tool locus as shown in FIG. 5, the curved line LIN is divided into a plurality of line elements Li with points Pn-1, Pn, Pn+1. . . , the curved line (~~including~~**or possibly a** straight line) connecting these points Pn-1, Pn, Pn+1. . . ~~with each other~~ is defined by a spatial polynomial expression as shown in an expression (B1) and an expression (B2).

[0047] If the whole length of this curved line defined is L, the whole length L is expressed by an expression (B3), and the line element Δ Li comprising the curved line LIN can be defined by an expression (B4). By giving **a** velocity profile ~~of~~**, namely by inserting a** velocity function F(t) expressed by an expression (B5)~~ having~~**, which expression has** time **as a** parameter t~~-on~~**,** this curved line LIN ~~to this expression (B4) so as to make the~~**with** expression (B4) and **with** the **velocity** expression**, expressions (B4) and** (B5) ~~equal to each other, an~~**produce** expression (B6)~~ is obtained~~. Then, λ and time t can be connected with each other.

[0048] This is substituted for the expressions (B1) and (B2) as shown in FIG. 6. ~~Then,~~**The** time parameter type polynomial can be obtained. Thereafter, commands ~~are~~ distributed to each axis on the basis of steps S3 and S4 of the ~~multiaxis~~**multi-axis** control program MAC, and the control in joint space allotted to each control axis~~ is~~**, are** executed as mentioned before.

[0049] The ~~before-mentioned embodiment refers to the case~~**foregoing embodiments concern the example,** of controlling ~~the~~**a** laser beam machine by the numerically controlled machine according to the ~~present~~ invention. ~~But~~**However**, the ~~present~~ invention **also** can be applied to ~~all~~**any other sort** of control ~~units for moving and controlling~~**unit that similarly moves and controls** an object ~~to be controlled~~ with **an** axis control~~ in addition to the control of the laser beam machine~~**. That is, the invention**

is not limited to positioning controls for laser beam machines and the like. Furthermore, **although a five axis control is discussed in the examples,** four control axes or less, and six control axes or more, can be ~~also~~ controlled ~~in addition to~~**instead of the exemplary** five axes ~~control~~.

[0050] The present invention is explained on the basis of the embodiment heretofore. The embodiments which are described in the present specification are illustrative and not limiting. The scope of the invention is designated by the accompanying claims and is not restricted by the descriptions of the specific embodiments. Accordingly, all the transformations and changes belonging to the claims are included in the scope of the present invention.

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